A.1.9 Call for Mission Concepts: Einstein Probes

1. Scope of Program

1.1 Overview

NASA's Structure and Evolution of the Universe (SEU) Theme has recently updated its Roadmap in support of the NASA Office of Space Science (OSS) strategic planning process. The new SEU roadmap, entitled "Beyond Einstein: From the Big Bang to Black Holes," covers the interval 2003 to 2028 (see http://universe.nasa.gov/) and places a high priority on addressing three fundamental questions about our Universe: What powered the Big Bang? What happens to space, time, and matter at the edge of a black hole? And what is the mysterious dark energy pulling the Universe apart? The Big Bang, black holes, and dark energy are all consequences of Einstein's theory of general relativity, and yet the underlying physics behind these phenomena is not understood. These phenomena represent the most extreme interactions of matter and energy with space and time and are the places to look for clues to the next fundamental revolution in understanding our Universe.

To find answers to these questions, the newest proposed SEU program, called *Beyond Einstein*, has three major elements that will work together towards twin visions of directly observing the birth of the Universe and directly imaging matter near the edge of a black hole. The cornerstones of the program are two Einstein Great Observatories, Constellation-X and the Laser Interferometer Space Antenna (LISA), that will provide dramatic new ways to answer questions about black holes, the Big Bang, and dark energy. The second element is a focused line of moderate-sized space missions called Einstein Probes, each dedicated to the study of a specific fundamental question. The third element is a supporting program of forward-looking technology development, theoretical studies, and education and public outreach.

1.2 Einstein Probes

This program element solicits proposals for concept studies of Einstein Probe missions that address any of the three focused science goals of the *Beyond Einstein* program that do not require facility-class observatories. These science goals are:

- Determine the nature of the dark energy that dominates the Universe;
- Search for the imprint of gravitational waves from inflation in the polarization of the cosmic microwave background; and
- Survey the Universe for black holes.

The Einstein Probes are currently planned to be fully competed, scientist-led mission opportunities with the goal to launch one such mission every three years, starting about 2010. The order in which the Einstein Probes are flown will be determined by both science priority and technological readiness. An Einstein Probe is envisioned as costing between $350M to $500M (real year $). Pending the submission to this solicitation of an

adequate number of proposals of merit, it is expected that approximately three mission concepts for each of these three science topics will be selected for further study.

1.2.1 Dark Energy Probe

The nature of the mysterious dark energy that dominates our Universe is one of the newest and most important questions facing cosmology and fundamental physics today. Probing dark energy requires measuring precisely how the expansion rate of the Universe is increasing with time over a large redshift range ($z \sim 0.5$ to 2). There are several plausible observational strategies that can achieve this goal, including using supernovae or other standard candles as a direct test of the distance/redshift relation, probing the evolution of cosmological perturbations through observations of large scale structure, and/or measuring the density of objects as a function of redshift. The Dark Energy Probe may use one of these techniques or some other technique requiring space-based observations to:

- Accurately determine the amount of dark energy, which currently is believed to comprise approximately 70% of the mass-energy of the Universe (improving the precision of this value will verify the existence of this mysterious component and further constrain its nature); and
- Determine whether the equation of state of the dark energy is constant or varies with time.

1.2.2 Inflation Probe

Just before the Universe became neutral, electrons scattered the cosmic microwaves, thus generating a pattern of polarization related to the temperature fluctuations of the Cosmic Microwave Background (CMB). Both density fluctuations and gravitons (gravitational wave quanta produced in the very early Universe) combined to determine this pattern. Fortunately, these two sources of fluctuations generate different patterns of polarization, which allows them to be separated. In particular, the graviton component is likely to be at least 100 times fainter than the density component. Therefore, the Einstein Inflation Probe is expected to:

- Map all the modes of polarization of the CMB to determine the sources of this polarization on both large and small scales; and
- Search the CMB for the signature of gravitational waves from the Big Bang to test theories of the very early Universe, such as inflation models.

1.2.3 Black Hole Finder Probe

The Black Hole Finder Probe will perform an all-sky imaging census of accreting black holes, from supermassive black holes in the nuclei of galaxies, to stellar mass black holes in our Galaxy. Since a veil of dust and gas currently hides most accreting black holes from our view this survey may best be carried out at high-energy x-ray, infrared, or radio wavelengths. Of these, hard x-rays may offer a promising method to distinguish black

hole emission from star formation by surveying the local Universe for black holes over a wide range of mass, obscuration, and accretion rates. The Black Hole Finder Probe may use this or other space based techniques to:

- Survey the local Universe over a wide range of black hole obscuration and accretion rates to identify the most luminous obscured black holes at larger redshifts in order to estimate the growth rate of massive black holes; and
- Discover ordinary stars being torn apart as they approach black holes.

2. Programmatic Information

2.1 Proposal Evaluation and Awards

Proposals will be assessed by one or more panels of individuals who are peers of the proposal teams in the relevant scientific and technical areas. This will be a single review, i.e., there will not be a separate review of the technical, management, or cost of the proposal.

A total of about $1M per year is available to support up to about nine mission concept studies for up to two years each (approximately three concept studies for each Einstein Probe described in Section 1.2 above).

Proposals for Einstein Probe concepts may include contributions from other agencies (national and international), industry, and universities. Proposals that enable collaboration with the National Science Foundation and/or Department of Energy are particularly encouraged, but such proposals must describe how the other agency could participate in the study.

2.2 Proposal Guidelines

As a modification to the material in Section 2.3.5 of the *Guidebook for Proposers – 2003* (see reference further below), the Scientific/Technical/Management section of proposals for this program element must include: 1) a clear statement of the scientific objectives that would be pursued by one of the three Einstein Probe mission investigations outlined in Section 1.2 above; 2) the associated technical developments seen as necessary to implement the mission investigation; 3) an implementation approach, including a "mission architecture;" and, as may be necessary, 4) a technology roadmap to enable that mission concept. Note that a proposal may not propose actual construction of hardware, even at the laboratory concept level. The relationship of the proposed mission to the present state of knowledge in the field, to the current readiness of needed technologies, and to any other relevant missions under development must also be discussed. Finally, this section of the proposal must contain a detailed statement of the work to be undertaken over the proposed period of performance, not to exceed two years, in order to develop the mission investigation concept and deliver a final report.

The mission concept must address one of the three science objectives noted above in Section 1.2. If a proposed mission can, without any additional cost or additions, address other science goals in the SEU theme or broader OSS strategic plan, they may be briefly discussed as secondary science objectives.

2.3 A Multi-Agency Approach to the Dark Energy Probe

The U.S. Department of Energy (DOE) has made the mystery of dark energy a high science priority and, under the leadership of its Lawrence Berkeley National Laboratory, is funding a study of a possible space mission entitled the Supernova Acceleration Probe (SNAP) to address this topic. Therefore, in order to encourage consideration of all possible approaches, as well as the potential of interagency collaborations, mission concept proposals for the Dark Energy Probe in response to this NASA solicitation may be of two types, both of which are encouraged with equal priority:

- Type 1: Proposals for a full mission investigation concept that uses any technique to meet the science goals of the Dark Energy Probe; and
- Type 2: Proposals involving a significant NASA contribution ($\geq$ 25% of the total mission cost) to the existing DOE SNAP concept mission. Note that prior endorsement from the SNAP team or DOE is not required, but the proposal must clearly state how the proposal team envisions working with the SNAP team to develop a joint concept.

2.4 Support for Mission Concept Development

During its period of performance, a selected investigator may want to utilize industry or a NASA Center to help develop the implementation approach, make trade-off studies, and/or evaluate the overall cost and feasibility. To this end, the NASA Goddard Space Flight Center's Integrated Design Capability (IDC) office will be available to aid the selected proposal investigators by providing rapid space system analysis and development of conceptual designs, including:

- Full end-to-end studies of an entire mission concept, including its system/subsystem concepts, requirements, and possible trade-offs;
- Focused studies of only part of a proposed mission;
- Independent assessments of investigator-provided studies/concepts; and/or
- New technologies and risk assessments

The IDC has two dedicated facilities: The Integrated Mission Design Center (IMDC), which provides specific mission design engineering analysis and end to-end mission design products tailored to fit an investigator's specific requirements and whose efforts are typically one week in duration ; and the Instrument Synthesis and Analysis Laboratory (ISAL), which provides design and analysis services focused on individual scientific instruments and whose efforts are typically two weeks or less in duration depending on instrument concept maturity and study objectives. The cost of utilizing either facility is $25K/week and, if anticipated, must be explicitly provided for in the

proposal budget. Further information about the IDC can be found at http://idc.gsfc.nasa.gov/ or from Ms. Ellen Herring, the IDC Operations Manager (Ellen.L.Herring@nasa.gov)

2.5 Supplemental Information

Further information on the SEU Beyond Einstein roadmap and the Einstein Probes can be found at http://universe.nasa.gov/.

IMPORTANT INFORMATION

As discussed in the *Summary of Solicitation* of this NRA, the Office of Space Science (OSS) now uses a single, unified set of instructions for the submission of proposals given in the document entitled *NASA Guidebook for Proposers Responding to NASA Research Announcement - 2003* (or *NASA Guidebook for Proposers* for short) that is accessible by opening http://research.hq.nasa.gov/ and linking through the menu item "Helpful References," or may be directly accessed at http://www.hq.nasa.gov/office/procurement/nraguidebook/ (note that the updated 2003-edition of the *Guidebook* is used for this solicitation). This NRA's *Summary of Solicitation* also contains the instructions relevant to the electronic submission of a Notice of Intent (NOI) to propose and a proposal's *Cover Page/Proposal Summary/Budget Summary*, as well as the mailing address for the submission of the hard copies of a proposal.

The schedule for the submission of Notices of Intent (NOI's) to propose, which are not required but encouraged, and of the hard copies of the proposals is:

- NOI Due Date: April 4, 2003
- Proposal Due Date (4:30 p.m. EST): June 13, 2003

Further information about this program may be obtained from the Program Scientist:

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